Finding Spirit: Teacher Information

Objectives: Students will apply linear and angular measurement techniques along with manipulation of scale factors to determine the latitude and longitude of the *Spirit* rover on the surface of Mars.

Grade Levels: 5-12

Time Frame: One to two 45-minute class sessions

Materials Needed:

- Student Instructions Handout
- Student Worksheet Pages (5) – Laminated, if possible
- Student Answer Sheets
- Protractor
- Metric Ruler
- Calculator

National Council of Mathematics Teachers *Principles and Standards*:

- Numbers and Operations: Work flexibly with fractions, decimals, and percents to solve problems.
- Numbers and Operations: Understand and use ratios and proportions to represent quantitative relationships.
- Measurement: Understand both metric and customary systems of measurement.
- Measurement: Select and apply techniques and tools to accurately find length and angle measures to appropriate levels of precision.
- Measurement: Solve problems involving scale factors, using ratio and proportion.

Procedure:

- Pass out the Student Instructions handout, the five worksheet pages (laminated, if possible), the student answer sheets, the protractor and ruler. [Note: By using laminated worksheet pages, you will be able to reuse images with additional classes. Be sure students use erasable markers on laminated sheets so sheets can be wiped clean after use.]
- Using Image #1, demonstrate the basic techniques of measuring distances on the image, calculating the image scale, and plotting the position of *Spirit* using its range and bearing. Remind your students that because of the differences in photocopiers, they may not get *exactly* the same measurement listed in the Student Instructions – but it should be close!
- Walk your students through completing Image #2. The procedure for completing Image #2 is exactly the same as the procedure for the remaining images.
- As you work through Image #2, stress to the students what is being accomplished in each step (reminders are printed to the right of each text

box). Remind your students that the calculations they are to perform are highlighted in **bold** in the text boxes. The general technique is summarized in the "Conversion Rules" section of the Student Instructions handout.

- Allow your students to continue through to Image #5 and read off the latitude and longitude of *Spirit*. Remind your students that because *Spirit* is in the southern hemisphere of Mars, latitude in the image increases as you go **south** rather than north.
- Note that while the students are asked to circle the two largest craters in each and use those for their calculations, any craters that can be seen in the current image and the next image will work. If they choose other craters for their measurements, their answers will not match the answer key, but they still should find the correct latitude and longitude for *Spirit*.

Assessment: The students should correctly locate *Spirit*'s position to within _ degree of latitude and longitude.

Vocabulary:

- Range
- Bearing
- Image Scale

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Finding Spirit
Student Instructions

Introduction

When the *Spirit* rover landed on 3 January 2004, one of the first things NASA wanted to know was "Where did *Spirit* land?" There is no Global Positioning System established at Mars, and our orbiting spacecraft have a very difficult time seeing something as small as *Spirit* on the surface. Fortunately, *Spirit*'s Entry, Descent, and Landing (EDL) System included a camera called the Descent Image Motion Estimation System (DIMES). This camera took three pictures that showed the area around the spacecraft as it descended. By combining the DIMES images with the engineering data sent by the spacecraft as it descended, *Spirit*'s controllers were able to determine exactly where the spacecraft came to rest, relative to a recognizable pattern of craters that were nearby.

The problem is that these craters are too small to appear on most maps of Mars! Fortunately, NASA currently has the *Mars Odyssey* spacecraft in orbit around Mars. Using *Odyssey*'s Thermal Emission Imaging System (THEMIS) camera, we can image both the small craters seen in the DIMES images and the larger craters that will help us find *Spirit* on a map of Mars. As you move through the five images in this activity, you will see more and more of Mars – almost as though you were zooming out your view. Your task is to use these images to find the latitude and longitude of *Spirit*'s landing site!

Range and Bearing

In order to find something on the surface, you need to know the direction in which it lies, called the **bearing**, and the distance it lies in that direction, called the **range**. Range and bearing are always measured from a **reference point**, or starting point. Take out your set of five images and look at image #1 (the images are numbered in the lower left corner). Use the crater labeled "1" as your reference point. The image lists the range from the center of crater 1 to crater 2 is 593 meters. Lay your protractor on the image so that the **grommet**, the hole on the center of the zero degrees line, is on the center of crater 1. Line up the zero degrees line so that it is pointing towards north – towards the top of the page in this and all the other images. What is the bearing from the center of crater 1 to center of crater 2? You should get a bearing of about 20 degrees from north. We write the range and bearing from crater 1 to crater 2 as "593 meters at 20 degrees."

[NOTE: Because of differences in photocopiers, your measurement may not be *exactly* the same as the numbers given here – but it should be close!]

What are the range and bearing from crater 2 to crater 1? The range is the same, 593 meters, but what is the bearing? Place your protractor so that the grommet is on the center of crater 2. Keep the zero degrees line so that it is pointing north (towards the top of the page, remember). If you have a standard protractor, you may see a problem here – the line to crater 1 is not under the protractor's measuring scale! Look at the **compass rose**, which labels all the directions, in the lower left of the page. The line from crater 2 to crater 1 is at a bearing of 180 degrees plus a little bit more. All you need to do is to

measure how far past the 180 degree line on the protractor the line to crater 2 lies. Rotate you protractor clockwise 180 degrees so that the zero degrees line is pointed directly *south* (towards the *bottom* of the page). We have now "counted off" 180 degrees, so how much further do we need to go to get to the line to crater 1? Read it off your protractor! You should get that we need about 20 degrees more to get to the line. 180 + 20 = 200 degrees, so the range and bearing from crater 2 to crater 1 are "593 meters at 200 degrees."

It's very important that you understand this technique, as you will be using it constantly in this activity.

Image Scale

You need to learn one other technique in order to find *Spirit*. We can't print these images to actual size – some would be as big as your entire city! Each image has a **scale**, a ratio that tells us how many meters on the surface of Mars are represented by each millimeter on the printed image. You need to calculate the scale of image #1. Measure the line between crater 1 and crater 2. You should get a measurement of about 76 millimeters (your printer may make this number slightly bigger or smaller). The *actual* distance between the craters is listed as 593 meters, so the scale of the image is:

593 meters / 76 millimeters = **7.8 actual meters per measured millimeter**

Be sure to fill in all of this information in the spaces at the top of image #1. Now you can convert back and forth between the distance we measure on the image with our rulers (in millimeters) and the actual distance on the surface of Mars (in meters). You can convert in either direction. For example, you will often need to measure the distance between two craters in millimeters and figure out how far apart the craters actually are on the surface of Mars. You do this by simply multiplying your measured distance times the scale of the image. You will get plenty of practice with this technique as you do this activity! In summary, below are the rules you will need to remember:

Conversion Rules:

1) **To convert from measured distances (in millimeters) to actual distances (in meters), multiply by the scale.**
2) **To convert from actual distances (in meters) to measured distances (in millimeters), divide by the scale.**

Determining Range and Bearing to *Spirit*

The procedure for finding *Spirit* is very simple. To get started, look at the bottom of image #1. You have been given the actual range from crater #1 to *Spirit*. Using the scale of image #1 and the rules listed above, calculate what the measured range to *Spirit* in image #1 should be and record it in the space provided. (We will use the term "distance" when referring to any general distance between two features in the image; we'll use the

term "range" when referring to the distance from the current reference point to *Spirit*.) You have also been given the bearing to *Spirit* from crater #1. To find *Spirit*'s location, put the grommet on the center of crater 1 with the zero degrees line pointing north. Since you need to get a bearing of 270 degrees, you will need to rotate your protractor 180 degrees and count off another 90 degrees. Mark this point with a dot so that you can draw a line from the center of crater 1 to this point. This line represents the bearing to *Spirit* from crater 1 in this image. Measure the distance (the measured range to Spirit) you calculated along this line and place an "x" – you've just found *Spirit*!

Spirit's Latitude and Longitude

Use the following instructions as a guide as you work with images #2 – #5. The instructions below provide an explanation of the steps you must complete with each image. We need to find *Spirit* on the larger-scale images so that we can determine the latitude and longitude of the spacecraft. Starting with image #2, your first task is to find the craters from the previous image in the current image. They will appear much smaller and closer together in the current image (the area shown by the previous image will be outlined on the current image), because they were taken with lower-resolution cameras. Once you have done this, follow the steps below:

Step 1: Find the scale of the current image.

In the current image, circle the two craters that you circled in the previous image. Remember that they will seem much smaller and much closer together in the current image! Make sure you see the pattern of the surrounding craters so that you are sure you have found the right craters. You know the actual distance between the two craters in the previous image (for example, in image #1 it was 593 meters), so now measure the distance between the centers of these same two craters in the current image. Dividing the actual distance by the measured distance (we write this mathematically as "actual distance / measured distance") gives us the scale of the current image. Record this number in the appropriate block on the current image.

Step 2: Find _Spirit_ in the current image.

You know the range and bearing from the largest crater in the previous image to *Spirit*. Using the scale of the current image, calculate the measured range from this crater to *Spirit*. Use the protractor to mark *Spirit*'s bearing and measured range on the current image. The bearing will be the same as what you measured in the previous image. Mark *Spirit*'s location on the image with an "x" any time you see the words "***NOW FIND SPIRIT!***"

Step 3: Circle the two largest craters in the current image and find the actual distance between them.

You may not always be able to see the craters you used in the previous image on the next image because they will be too small. For that reason, you need to find two larger craters that you *will* see in the next image to use for Step 1 in the next image. Make sure you can see all of each crater that you choose, and measure the distance from crater center to crater center. Circle the two craters you have chosen. Record this number

in the appropriate block on the current image. Determine the actual distance between the two craters using the conversion rules (the worksheets will remind you which rule to use) and record this number in the appropriate block on the current image.

Step 4: Find the range and bearing to *Spirit* from the largest crater in the current image.

Just as in Step 3, you may not be able to see the crater from the previous image in the next image, so you must find the actual range and bearing to *Spirit* from a larger crater that you *will* be able to see. Draw a line from the largest crater to where you placed an "x" to mark *Spirit*'s location. Measure the range and bearing from this crater to *Spirit*. Convert your measured range to the actual range on the surface of Mars using the conversion rules you have learned. Record these numbers in the appropriate block on the current image.

You will perform Steps 1-4 for image #2, #3, and #4 until you are able to find *Spirit* on image #5, in which you will be able to determine *Spirit*'s latitude and longitude. Be sure to fill in all the data as you move from one image to the next. Refer back to these student instructions as necessary to remind yourself of how to get the numbers you need. The boxes on each image provide you with a brief reminder of what you are doing in each step. Good hunting!

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